Accuracy of CAD/CAM-guided template to locate abutment screw access hole in cement-retained implant crowns

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Accuracy of CAD/CAM-guided template to locate abutment screw access hole in cement-retained implant crowns

(Directed by Prof. Keun Woo Lee, D.D.S.,M.S.D.,Ph.D.)

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감사의 글

이 논문이 완성되기까지 학위 과정뿐 아니라 여러 면에서 부족한 저를 이끌어 주시고 격려와 세심한 조언을 주신 이근우 교수님께 항상 고마움을 느끼고 깊은 감사를 드립니다. 또한, 논문의 작성과 심사에 귀중한 조언과 격려를 해주신 심준성 교수님, 이재훈교수님, 한중석 교수님, 김형섭 교수님께 깊은 감사를 드립니다. 그리고 항상 따뜻한 관심과 격려로 지켜봐 주신 조성암 교수님, 이청희 교수님, 이규복 교수님, 조진현 교수님께도 감사 드립니다.

모든 것이 합력하여 선을 이룬다는 것을 깨닫게 해주시며 항상 좋은 길로 인도해 주시는 하나님께 감사를 드리며 영광을 돌립니다. 영혼 사랑을 지향하는 지식 탐구를 하며 기독 사랑을 실천하는 최적의 진료를 하겠다는 것을 다짐해 봅니다.

끝으로 언제나 한결같은 사랑과 내조로 든든한 버팀목이 되어주고 나를 믿고 따라준 가장 사랑하는 나의 아내 정원과 형언할 수 없는 사랑으로 아들을 믿어 주시는 아버지, 어머니 그리고 장인어른, 장모님께 마음을 담아 이 논문을 바칩니다.

2016 년 6 월

이두형 드림

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Abstract

Accuracy of CAD/CAM-guided template to locate abutment screw access hole in cement-retained implant crowns

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(Directed by Prof. Keun Woo Lee, D.D.S.,M.S.D.,Ph.D.)

Purpose: The formation of screw-access hole for cement-retained implant restorations can be aided by using a computer-assisted design and computer-assisted manufacturing (CAD/CAM) drilling guide. The purpose of this study was to evaluate the accuracy of the CAD/CAM- guided template for drilling the screw-access hole in malpositioned implants.

Materials & Methods: Experimental factors were implant angulation and position. Eighteen students prepared screw-access holes through the crowns of implants placed at 0-, 15-, and 30-degree angulations in the mandibular second molar on dental casts. Another twenty students prepared the holes through the crowns of implant placed lingually on premolar and molar. Experimental and control groups differed in the use of a CAD/CAM screw-hole drilling guide, and each group was subdivided according to implant angulation and position. The preparation accuracy was evaluated in terms of the volume losses of crowns and abutments, the angular deviation of hole, and drilling entry point. An independent *t* test and two-way analysis of variance (ANOVA) with the Tukey honestly significant difference (HSD) test were performed to analyze intergroup differences and interactions (α=0.05).

Results: The implant angulation and position significantly influenced the effect of the drilling guide with regard to the accuracy of the screw-hole (F=8.319, P<0.05) and crown volume loss (F=4.474, P<0.05). For the 30-degree angulation, the guided drilling group exhibited smaller screw-access holes than the freehand drilling group (P<0.05), whereas no statistical differences were found between the groups for the 0- or 15-degree angulations. The accuracy of drilling entry point significantly correlated with prosthesis position and guide use (F = 51.281, P<0.05). The overall standard deviation was smaller in the guided drilling group than in the freehand drilling group.

Conclusion: A CAD/CAM guide template significantly enhances the accuracy of drilling the screw-hole and reduces damage to the crown and abutment, particularly at 30-degree angled and lingually placed implants.

Key words: Dental implants, Screw access hole, Drilling guide, CAD/CAM, Accuracy

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I. Introduction

Implant fixed dental prostheses are a favorable treatment modality for recovering masticatory function and esthetics without interfering with adjacent teeth in partially edentulous patients.[1,2] Cementation and screw engagement are the two major mechanisms for retaining the coronal restoration of the implant abutment.[3,4] Despite the favorable esthetics, occlusion, and passive fit of cement-retained implant prostheses, difficult retrieval is a drawback.[5,6] The retrievability of implant restorations is essential to manage complications related to prosthodontic concerns such as screw loosening or porcelain fracture.[7,8] Excessive nonaxial forces can catalyze screw loosening or fracture, leading to prosthesis failure.[9] Therefore, to avoid prosthodontic complications, the axis of the implant should be parallel to the axis of the occlusal loading forces during masticatory function.[10,11] However, axial placement is not always possible because of anatomic limitations, including the pneumatization of the maxillary sinus, proximity of the inferior alveolar nerve, and lack of available native bone.[12,13] Moreover, in particular treatment concepts, angled implant placement may be intentionally planned to achieve biomechanical advantages and avoid bone grafting procedures.[10,12]

When prosthodontic complications occur, retrieval of the crown is necessary. Although creating a screw-hole within the crown is a less destructive method than crown sectioning and can avoid serious damage to the crown, locating the exact position of the screw-hole in the narrow interarch space is difficult. Several visual guidance methods have been reported in the literature to facilitate screw-hole preparation. The periapical radiograph is a basic guideline for estimating the implant position.[14] Digital photographs using a superimposition technique are another visual tool for recording the position of prosthetic abutments.[15,16] External staining on the occlusal surface of the crown has also been suggested to indicate the location of the abutment.[17] Although visual guidance methods are effective in determining the entry point for drilling, their ability to indicate the exact orientation for drilling is limited. Thus, physical guidance methods for not only the entry point of drilling but also the angulation of drilling have been developed.[18,19] Recently, a more advanced technique using computer-assisted design/computer-assisted manufacturing (CAD/CAM) and digital scanning for fabricating a screw-hole drilling guide has been reported.[20] The technique reduced conventional manual labor and mitigated the issue of stone cast storage.

The guide concept was first introduced to implant surgery as a surgical template to guide the creation of the osteotomy and subsequent implant insertion.[21,22] Previous studies demonstrated that the use of a surgical template significantly increases the accuracy and predictability of implant bed preparation compared with freehand drilling.[23,24] Surgical templates can be classified as nonlimiting or limiting designs on the basis of the extent of their guidance.[25] Nonlimiting designs only indicate initial points of drilling, whereas limiting designs restrict surgical instruments not only in the drilling angulation and pathway but also in the depth of the osteotomy. As for guide fabrication methods, conventional and CAD/CAM-based techniques are available. The conventional technique, in which the approximate location of vital structures is determined, is based on gypsum casts and 2-dimensional radiographs.[26] The CAD/CAM-based technique, however, uses digital scanning, computed tomography, design software, and a machining process to directly show hard and soft tissue in 3 dimensions (3D).[27] CAD/CAM-based surgical templates can provide 3D guidance during osteotomy[28] and are thus more accurate than conventionally fabricated surgical templates.[29-31]

The recently introduced CAD/CAM screw-hole drilling guide for cement-retained implant prostheses has a limiting design.[20] The fabrication process of the screw-hole drilling guide is similar to that of computer-assisted surgical templates for implant surgery. Thus, it serves as a transfer device for the starting point and angulation in drilling a hole to access the abutment screw. However, the accuracy of CAD/CAM screw-hole drilling guides has not been demonstrated. The purpose of this study was to evaluate the effect of this CAD/CAM screw-hole drilling guide with regard to the accuracy of screw-hole preparation and damage to the crown and abutment in angled implant models and in lingually placed implant models by using microcomputed tomography (micro-CT) and image analysis software. The first null hypothesis was that the use of a CAD/CAM guide does not affect the accuracy of screw-hole preparation or minimize damage to the crown and abutment in malpositioned implants. The second null hypothesis was that implant angulation does not influence the accuracy of screw-hole preparation.

II. Materials and Methods

2.1. Experimental model preparation

2.1.1. Angled implant model

Three partially edentulous mandibular stone casts with missing left second molars were prepared. An implant of 5.0 mm in diameter and 10.0 mm in height (SuperLine, Dentium, Seoul, Korea) was placed on each cast at 0, 15 or 30 degrees to a line drawn perpendicular to the occlusal plane (Fig. 1), and an implant abutment (Dual Abutment; Dentium) was then connected to the implant.

Fig. 1 Master model with angled implant. A. 0 degree. B. 15 degrees. C. 30 degrees

2.1.2. Lingually placed implant model

Four partially edentulous mandibular casts, missing a first premolar and missing a second molar, were prepared. The 5.2-mm-thick plaster was trimmed on the buccal side of the edentulous ridge to represent the horizontal alveolar bone defect.[32] An implant 4.5 mm in diameter and 10.0 mm long (AnyOne, MegaGen Implant, Daegu, Korea) was placed at the ridge crest of the edentulous area. A prefabricated titanium implant abutment with a

4.5-mm profile diameter, 2.5-mm cuff height, and 4-mm post height (EZ post, MegaGen Implant) was connected to the implant (Fig. 2).

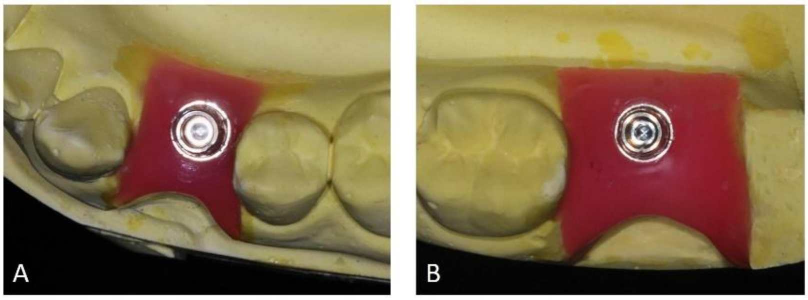

Fig. 2 Horizontal alveolar bone resorption model with lingually placed implants. A. First premolar area. B. Second molar area

2.2. Restoration fabrication

The abutments were scanned with a desktop scanner (Ceramill Map 400, Amann Girrbach, Koblach, Austria). Definitive crowns were designed using a CAD program (Ceramill Match 2, Amann Girrbach). A total of 188 crowns (108 for angled implant model, 80 for lingually placed implant model) were milled in a milling machine (Ceramill Motion 2, Amann Girrbach) using polymethyl methacrylate and methacrylic acid ester-based cross-linked resin blocks (Ceramill TEMP, Amann Girrbach).

2.3. Screw-hole drilling guide fabrication

The screw-hole drilling guides were fabricated using a 3D image superimposition technique[33] and CAD/CAM technologies.[20] A metal column of 1.5 mm in diameter and 20.0 mm in height was inserted into the screw hole of the prosthetic abutment (Fig. 3), and the first optical scan was acquired with the desktop scanner. The definitive crown was cemented after removing the column from the abutment. The second scan of the crown was performed under the supposition that the abutment screw was loosened. The 2 scanned images were exported to a dental design software program (DDS-Pro 1.4.7, Digital Dental Service, London, England) in surface tessellation language (STL) format. The image superimposition process was performed using the software to indicate the path of the screw-hole through the crown (Fig. 4). Three anatomic landmarks from intact teeth were manually selected to match the two 3D images.

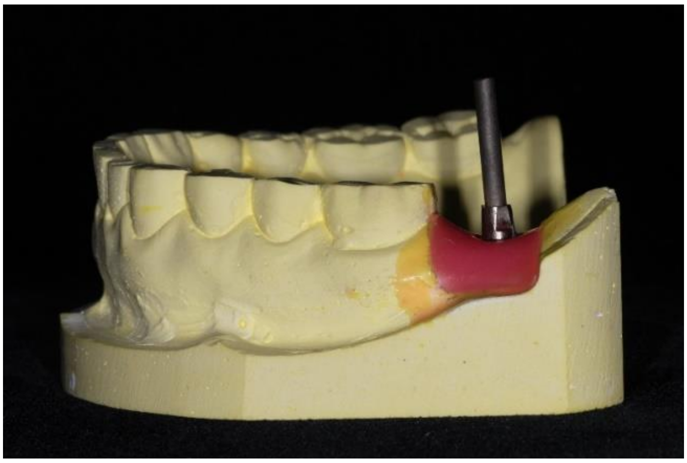

Fig. 3 Insertion of metal column into the screw hole of the prosthetic abutment

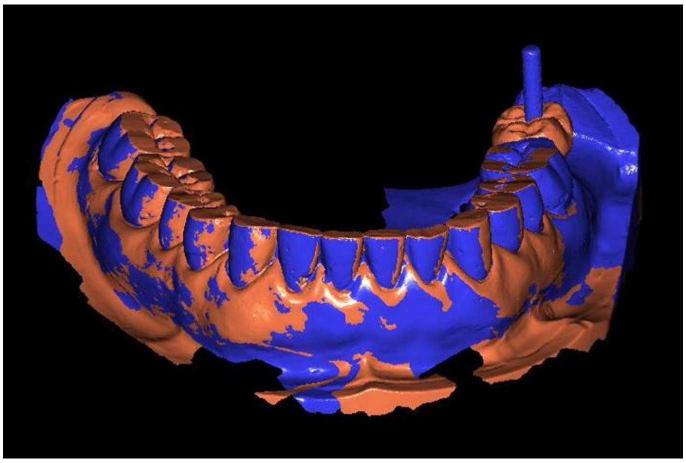

Fig. 4　Image superimposition to indicate the path of the screw-hole through the crown

After superimposition, the design software was used on the merged image to design the drilling guide to cover the prosthetic crown and two and a half adjacent teeth at the height of the contour level. A guide sleeve of 4.5 mm in height was added at the position of the column to facilitate drilling (Fig. 5).[34] A transparent acrylic resin guide template was fabricated using a 5-axis milling machine (Ceramill Motion 2) and a polymethyl methacrylate and methacrylic acid ester-based cross-linked resin block (Ceramill PMMA; Amann Girrbach; Fig. 6).

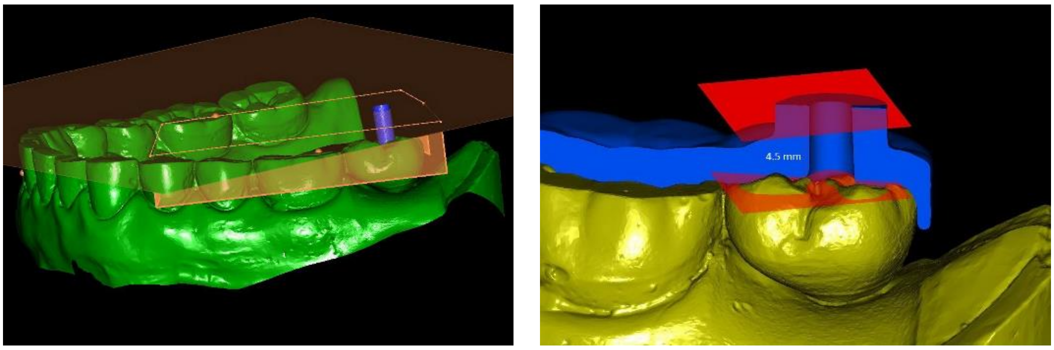

Fig. 5　Drawing of guide on virtual cast with dental design software

Fig. 6 Fabricated drilling guide

2.4. Operator groups

The experimental group was the CAD/CAM guide group, and the control group was the freehand group.

2.4.1. Angled implant experiment

Eighteen third-year postgraduate students blinded to the research objective were included as operators. Each condition was subdivided based on implant angulation and the used of guide: 0-degree implant angle, freehand drilling (0F); 0-degree implant angle, guided drilling (0G); 15-degree implant angle, freehand drilling (15F); 15-degree implant angle, guided drilling (15G), 30-degree implant angle, freehand drilling (30F); and 30-degree implant angle, guided drilling (30G). All students performed the hole drilling at the each condition.

2.4.2. Lingually placed implant experiment

Twenty third-year postgraduate students were included. Conditions were divided into two subgroups based on the use of guide and position of the missing tooth: freehand drilling, premolar (FP); freehand drilling, molar (FM); guided drilling, premolar (GP); and guided drilling, molar (GM). All students performed the hole drilling at the each condition.

2.5. Screw-access hole formation

The study casts were securely clamped in phantom heads (PH-1-DK, Shinhung Co Ltd, Seoul, Korea), and the operators prepared an abutment screw-access hole through the crown. Periapical radiographs showing the implant and adjacent teeth were provided to mimic a clinical setting (Fig. 7A). Each operator performed drilling actions under each condition with a crown-cutting rotary instrument (H7 FG 330, Komet, Rock Hill, SC, USA) and a cylindrical, coarse-grit diamond rotary instrument (FG 951KR-019, Komet) at high speed under water spray (Fig. 7B). When the abutment screw was completely removed, the drilling procedure was completed.

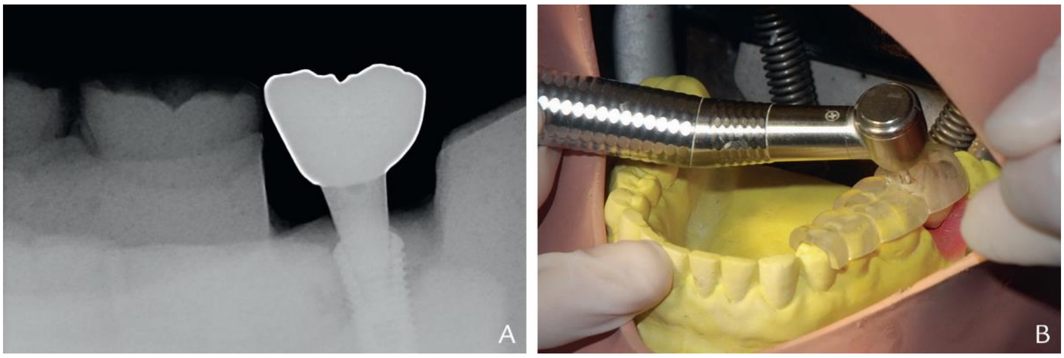

Fig. 7 A. Periapical radiograph showing position and angulation of implant. B. Drilling screw hole in dental phantom model

2.6. Micro-computed tomographic analysis

To visualize the preparation geometry, the screw-access hole in the crown was filled with injectable thermoplasticized gutta percha using the Obtura II system (Model 823-700, Obtura Spartan, Fenton, MO, USA). Crowns were scanned using a micro-CT (X-EYE CT system, SEC Corporation, Seoul, Korea) with the following conditions: 80 kV, 90 μA, 30 μm resolution, 300 ms exposure time, and 20 minutes total scan time (Fig. 8). A total of 512 two-dimensional (2D) images were acquired for each specimen. The raw micro-CT data were saved in Digital Imaging and Communication in Medicine (DICOM) format, and the crown region was segmented from the whole data to designate a region of interest (ROI) using CT-Analyzer software (CTAn v.1.15, Bruker-MicroCT, Kontich, Belgium). Subsequently, the selected area was converted to a 3D reconstruction image to visualize the screw-access hole in STL format.

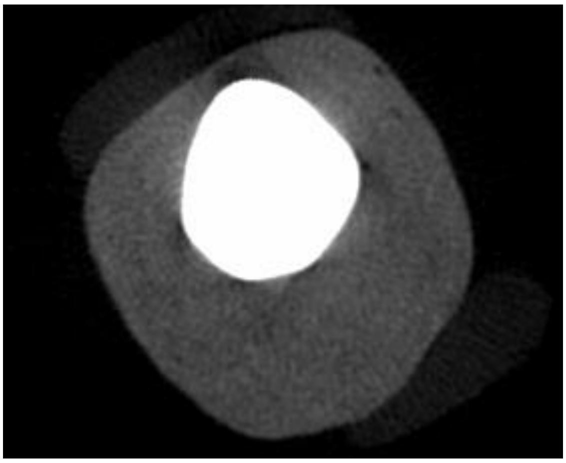

Fig 8. Cross-sectional image of micro-computed tomography of crown

2.7. Three-dimensional measurement of preparation geometry

The accuracy of the screw-access hole in the crown was evaluated with regard to volume loss of crown, angular deviation of hole, positional deviation of drilling entry point. (Fig. 9). The crown volume loss was measured using the 3D reconstruction image of screw hole. The angular deviation was recorded by calculating the 3D angle between the longitudinal axes of the abutment and the prepared screw hole. These measurements of geometric outcome variables were performed with image analysis software (Geomagic Qualify, Geomagic, NC, USA) (3-Matic, Materialise, Leuven, Belgium) (Fig. 10). The deviation of the entry point of drilling was evaluated by measuring the distance between the ideal and actual entry points. For the measurement, two similar photographs of the stone cast were taken.[35] One photograph was a shot showing the abutment position without the restoration, while the other was a shot of the restoration on the abutment showing the actual drilling entry point that was taken when the initial drilling was performed. The two photographs were imported into Photoshop (Adobe Systems, San Jose, CA, USA) and closely superimposed. A line connecting the center point of the abutment and actual entry point of drilling was drawn and its length was measured.

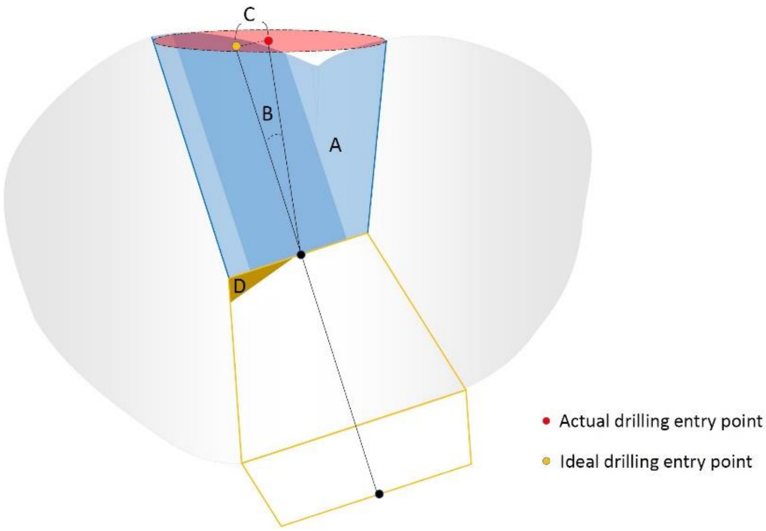

Fig.9 Definition of measurement parameters. A. Crown volume loss. B. Angular deviation. C. Drilling entry point deviation. D. Abutment volume loss

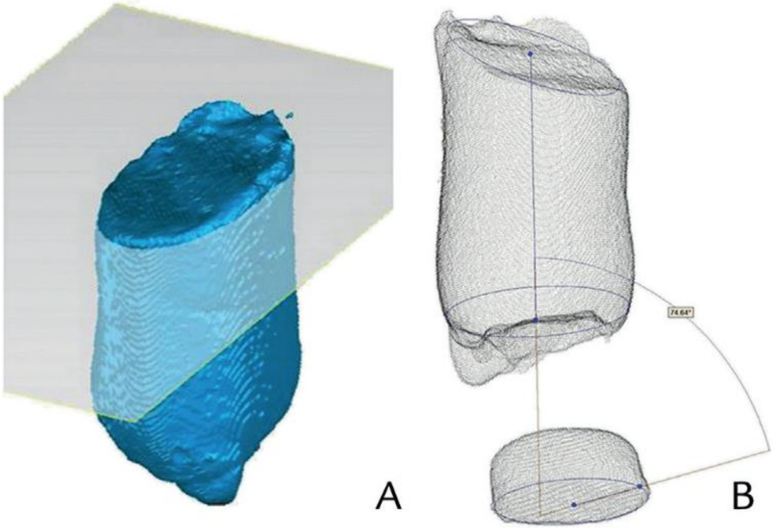

Fig.10 Three-dimensional evaluation of screw-hole. A. Volumetric analysis. B. Angular analysis

To analyze abutment damage after drilling, the abutment volume loss was calculated by subtracting the volume of the damaged abutment from that of the intact abutment. Each abutment was digitized using the desktop scanner before and after drilling, and data were exported as an STL-format file to the image analysis software program (Qualify 12, Geomagic), where the volume loss was computed (Fig. 11). All measurements were recorded by a single trained examiner, who was not involved in the experiment.

Fig.11 Superimposed image between intact and damaged abutments. Gray area shows volume loss incurred from drilling

2.8. Statistical analysis

Software (SPSS v22.0 for Windows, SPSS Inc., Chicago, IL, USA) was used for all statistical analyses.

2.8.1. Angled implant experiment

The independent *t* test was used to analyze significant differences between the freehand and guided drilling groups. One-way analysis of variance (ANOVA) with the Tukey honestly significant difference (HSD) post hoc test was used to verify the influence of implant angulation. The Shapiro-Wilk test and Levene test were used to verify the normality of distribution and the equality of data variances. Two-way ANOVA was used to verify the interaction between guide use and implant angulation. The significance level was set at 0.05.

2.8.2. Lingually placed implant experiment

The independent *t* test was used to analyze significant differences between the freehand and guided drilling groups. Two-way ANOVA was used to verify the interaction between guide use and missing tooth position. The Shapiro-Wilk test and Levene test were used to verify the normality of distribution and the equality of data variances. The significance level was set at 0.05.

III. Results

3.1. Effects of CAD/CAM-guided template in angled implants

The box plot (Fig. 12) shows the data for crown volume loss under the 6 conditions using 5 statistics: maximum, third quartile, median, first quartile, and minimum. The volume loss was significantly larger with the 30-degree angulation than with the 0- and 15-degree angulations (P<0.05). The volumes were smaller and more consistent in each guided drilling group compared with the corresponding freehand drilling groups, although the differences were not significant for the 0- and 15-degree angulations (P=0.128 and 0.161, respectively). Two-way ANOVA (Table 1) revealed a significant interaction between drilling technique and angulation (F=4.474, P<0.05).

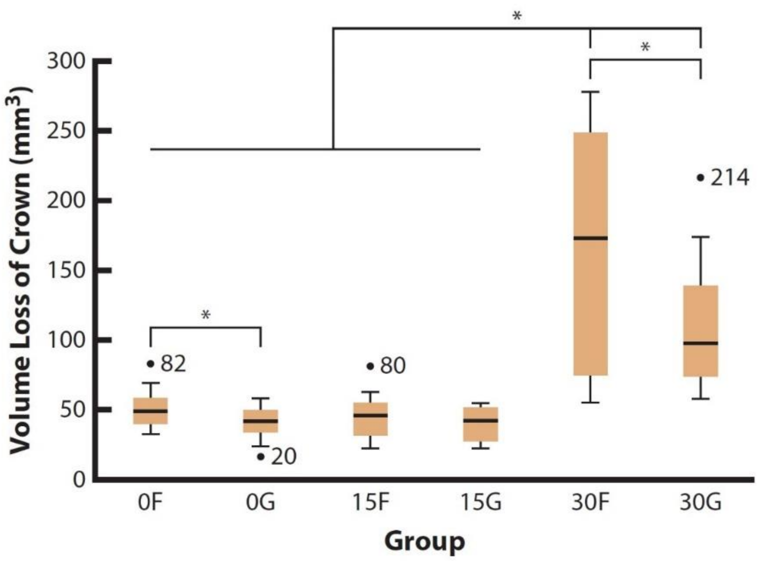

Fig.12 Box-plot diagram for volume loss of crown, by use of guide and implant angulation. 0F., 0-degree implant angle, freehand drilling; 0G, 0-degree implant angle, guided drilling; 15F, 15-degree implant angle, freehand drilling; 15G, 15-degree implant angle, guided drilling, 30F, 30-degree implant angle, freehand drilling, 30G, 30-degree implant angle, guided drilling

Table 1. Two-way ANOVA for volume loss of crown

Variables of Interest	**Sum of Squares**	**Mean Square**	**F**	***P***
Drilling Freehand/Guided	11586.966	11586.966	8.073	<0.05
Angulation (degrees) 0/15/30	176276.757	88138.378	61.406	<0.05
Drilling × Angulation	12843.402	6421.701	4.474	<0.05

Table 2 shows the means and standard deviations for the angular deviations. No significant differences were found between the 0- and 15-degree groups, whereas deviations in the 30-degree groups were significantly larger than those in the other groups (P<0.05). Thus, the accuracy of the screw hole varied with implant angulation. The guided drilling groups exhibited smaller deviations than did the freehand groups for the 0- and 30-degree angulations; for the 15-degree angulation, deviations were higher in the guided drilling group than in the freehand drilling group. However, the differences among groups were not statistically significant (P=0.791).

Table 2. Means ± SD values for angular deviations in screw holes

Implant angle	0		15		30	
Drill method	**F**	**G**	**F**	**G**	**F**	**G**
Angular deviation (°)	8.543 ±4.101[a]	7.217 ±3.282[a]	8.654 ±4.938[a]	18.821 ±4.637[a]	20.909 ±11.982[b]	13.866 ±6.772[b]

F, freehand drilling; G, guided drilling.

[a,b] The same superscripted symbols represent statistically similar groups (*P*<0.05).

No significant differences in abutment volume loss were found among groups, except for the freehand drilling group under the 30-degree condition (Table 3; *P*<0.05). In general, standard deviations were smaller in the guided drilling groups than in the freehand drilling groups.

Table 3. Means ± SD values for abutment volume loss

Implant angle	0		15		30	
Drill method	**F**	**G**	**F**	**G**	**F**	**G**
Abutment volume loss (mm^3)	1.411 ±1.063[a]	1.188 ±0.780[a]	1.553 ±1.011[a]	1.459 ±1.084[a]	3.816 ±2.038[b]	2.462 ±1.223[ab]

F, freehand drilling; G, guided drilling.

[a,b] The same superscripted symbols represent statistically similar groups within row (*P*<0.05).

3.2. Effects of CAD/CAM-guided template in lingually placed implants

The mean volume and entry point deviation were significantly smaller in the guided drilling groups than in the freehand drilling groups (P<0.05) (Fig. 13). The box plots show the data for the volume and entry point deviations under the four conditions (Fig 14, 15). Two-way ANOVA revealed a significant interaction between the guide and edentulous position factors (F = 51.281, P<0.05), and the guided drilling was revealed as more effective in the molar than premolar area. There were no significant differences in angular deviations among groups. Overall standard deviation was smaller in the guided drilling group than in the freehand drilling group.

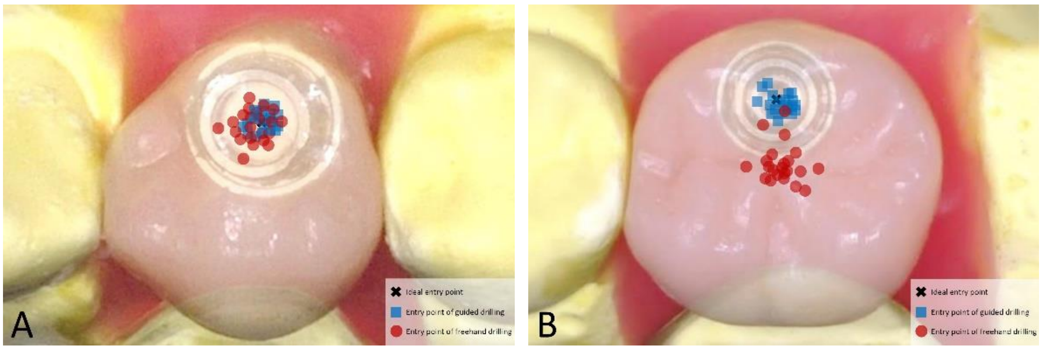

Fig. 13 Distribution of entry points of drilling in the guided and freehand drilling groups. A. Premolar. B. Molar

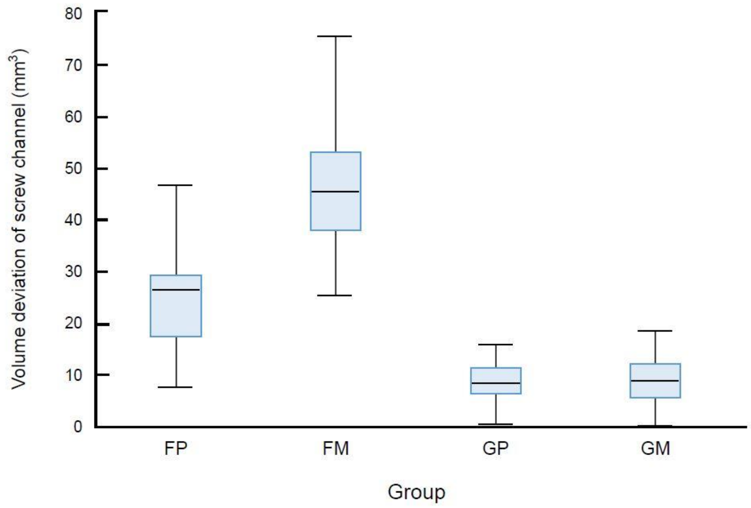

Fig. 14 Box-plot diagram for volume deviation of screw hole, by use of guide and implant position. FP, freehand drilling, premolar; FM, freehand drilling, molar; GP, guided drilling, premolar; GM, guided drilling, molar

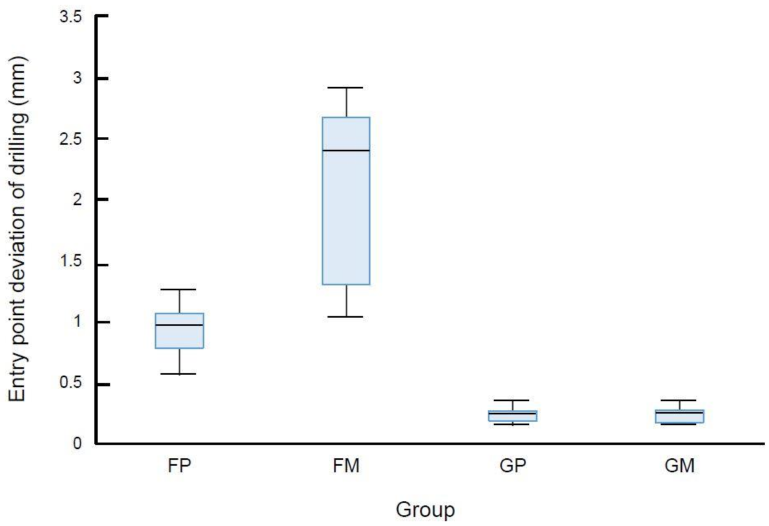

Fig. 15 Box-plot diagram for entry point deviation of drilling, by use of guide and implant position. FP, freehand drilling, premolar; FM, freehand drilling, molar; GP, guided drilling, premolar; GM, guided drilling, molar

IV. Discussion

This study evaluated the accuracy of CAD/CAM guides with regard to screw-hole preparation and damage to the implant restoration in angled implant models and lingually placed implant models using micro-CT and image analysis software. The use of a CAD/CAM guide enhanced the accuracy of the screw hole in the crown and reduced morphological alterations in the crown and abutment. Thus, the first null hypothesis that the use of a CAD/CAM guide does not affect screw-hole accuracy or minimize damage to the crown and abutment was rejected. The results correspond well with those of surgical guide studies, which confirmed the improvement of implant bed preparation by using a surgical template.[23,24] Additionally, the high precision of the CAD/CAM-based guide may lead to less destructive preparation of screw holes.[29-31]

The inaccuracy of the screw-hole was markedly greater when the implant was placed at 30 degrees; therefore, the second hypothesis was also rejected, proving the intimate relationship of the implant angulation and use of the CAD/CAM drilling guide with screw-hole accuracy. Therefore, the use of such drilling guides is recommended for extremely tilted implants.

The drilling entry points were more accurate and precise in the guided groups than in the freehand groups. The entry points of the guided group were localized over the abutments, whereas the entry points of the freehand group were formed around the central fossa of the crown. Based on the entry point distribution, it is assumed that, in the without-guide condition, most operators were affected by the occlusal anatomy and used the central fossa as a reference to start the initial preparation. This preparation pattern acted favorably in the premolars because the central fossa is lingual-sided, which leaded to less entry point deviation to the lingually placed implants. However, in the molars, this preparation pattern caused high deviation from the ideal entry point because the central fossa of the molar sits around center of the occlusal surface. Accordingly, the entry point accuracy was significantly different between the premolar and molar restoration in the freehand drilling groups. On the other hand, guide use completely excluded the impact of occlusal morphology in determining the drilling starting point. Thus, the entry point accuracy was similar regardless of prosthesis position. This study's results show that the screw-hole drilling guide is a useful tool for determining the drilling entry point close to the abutment by limiting the possible preparation area.

The volume losses of the crown were calculated to assess the accuracy of the guide for drilling a screw hole. The amount of volume loss is clinically important because it closely relates to the function and esthetics of the prosthesis. When the formed screw hole is large, the occlusal scheme is restricted, and occlusal contacts cannot be established over the implant. This causes not only masticatory inefficiency but also a cantilever effect that can cause loosening and fracture of the abutment screw.[36] Moreover, occlusal anatomic characteristics cannot be reproduced. The volume loss is also associated with the durability of the prosthesis; excessive volume loss weakens the crown. Consequently, when the screw hole is invasively prepared, remaking the crown becomes inevitable. Therefore, measuring crown volume losses seems to be relevant and indispensable for evaluating the accuracy and efficiency of the drilling guide.

Angular deviations of the prepared screw holes were additional elements for determining the accuracy of the drilling guide. Overall, deviations were high for the 30-degree angulation and with freehand drilling. Interestingly, however, the mean deviation in the freehand drilling group was slightly smaller than that in the guided drilling group for the 15-degree angulation. Although the difference in deviations was not statistically significant because of large standard deviations, this result is not in accordance with the other findings of our study. The first possible reason is the influence of the 15-degree implant angulation. In a clinical setting, the visualization of and access to the molar area is limited because of the narrow interarch space. Placing an implant with a mesial angulation in this region may provide better visualization and access for instrumentation. Because the mandibular second molar region was used in this study, a 15-degree implant angulation may have been more favorable compared with axial placement. The second possible explanation is the influence of the operator's ability to use the guide. A few participants in this study experienced difficulty while drilling the screw hole using an in-and-out motion through the guide sleeve, and some unintentionally ground the sleeve further during preparation. As a result, several large deviations resulted in outliers that increased the mean deviation values for the guided drilling group.

Abutment damage is another important factor during screw-hole drilling. Severe abutment damage can decrease the clinical longevity of the implant restoration by decreasing the retention force of the crown and weakening the durability of the abutment. In this study, abutment volume losses were not significantly different among groups, probably because of the drilling method. A crown-cutting rotary instrument was first used to perforate the crown, while a cylindrical diamond rotary instrument was used to enlarge the entry hole. Abutment damage occurred mostly during hole enlargement. While the guide was used during initial drilling, enlargement was performed without the guide. Therefore, use of the guide did not directly affect the amount of abutment loss. Modification of the guide sleeve and instrumentation may thus be necessary to minimize abutment damage during guided drilling.

Methodologically, micro-CT was employed in this study to visualize the formed screw-hole. Micro-CT is a non-destructive method for investigating inside object, and provides precise 3D images for both quantitative and qualitative analyses using multiple X-ray projections with different angles.[37-39] Since the use of micro-CT was first recommended to assess bone morphology and microarchitecture, its applications were recently expanded to prosthetic studies for internal gap and shrinkage of dental restorations.[40] The micro-CT can supply the complete 3D morphology of the restoration internal gap and visualize internal deformations of dental composites. In the present study, we used micro-CT to determine the morphology of the formed screw hole. To distinguish the hole area from the crown, the gutta percha radiopaque material was obturated into the space. Since the material has a different ability to attenuate the X-ray from the surrounding images, the formed screw-hole area was clearly separated from the surrounding area, which enabled precise 3D reconstruction of the formed screw-hole. Thus, micro-CT is considered a suitable tool for analyzing the preparation geometry of the screw-access hole.

With the increasing use of dental implants, valid measures for retrieving implant prostheses become more important. For an in vitro study design, the clinical situation must be replicated as closely as possible to strengthen the clinical relevance of the results. Although this study was designed to simulate the actual clinical setting by providing periapical radiographs and conducting drilling sessions inside the oral cavities of phantom heads, the findings are limited by the exclusion of patient factors. More comprehensive clinical studies are necessary to assess clinical proficiency, procedural duration, convenience, and satisfaction to confirm the results of the present study.

V. Conclusion

The purpose of this study was to evaluate the accuracy of CAD/CAM-guided template for drilling the screw-access hole in angled and lingually placed implants by using micro-CT and image analysis software. In spite of experimental limitations and difficulties, the following results were obtained:

1. The use of a CAD/CAM screw-hole drilling guide improved the accuracy of the screw-access hole and minimized damage to the crown and abutment, and the effect of the guide became evident when an implant was tilted by 30 degrees.
2. The use of a CAD/CAM screw-hole drilling guide enhanced the initial orientation of drilling and hole preparation in lingually placed implants by excluding the impact of occlusal morphology.
3. CAD/CAM screw-hole drilling guides should be recommended to enable less-destructive hole preparation and facilitate crown retrieval for malpositioned implants.

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국문요약

시멘트 유지형 임플란트 보철물에서
CAD/CAM 방식의 가이드 형판을 이용한
나사 접근 구멍의 형성 정확성

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이두형

목적: 시멘트 유지형 임플란트 보철물에 지대주 나사 접근 구멍을 형성하는 과정은 CAD/CAM 으로 제작된 가이드 형판으로 쉽게 할 수 있다. 본 연구의 목적은 CAD/CAM 방식의 가이드 형판의 사용 여부에 따른 나사 접근 구멍의 정확성을 마이크로 컴퓨터 단층촬영과 컴퓨터 소프트웨어를 이용하여 3 차원적으로 비교 평가하는 것이다.

방법: 구치부에 0, 15, 30 도의 근심경사로 임플란트를 식립한 모형과 인접치보다 설측으로 임플란트를 식립한 모형을 제작 후, 각각 18 명과

20 명의 술자가 해당 임플란트 보철물에 나사 접근 구멍을 형성하였다. 가이드 형판의 사용 유무에 따라 실험군과 대조군으로 나누고, 식립 각도와 위치에 따라 세부 군으로 분류하였다. 분석을 위해 구멍이 형성된 보철물을 마이크로 컴퓨터 단층촬영 장치로 촬영하고 영상을 컴퓨터 소프트웨어를 이용하여 계측하였다.

결과: 가이드 형판의 사용 유무는 임플란트 식립 각도와 식립 위치에 따른 나사 접근 구멍 형성의 정확성에 영향을 미쳤다. 임플란트가 30 도 경사진 경우에는 가이드 형판의 효과가 유의하게 나타났으나, 작은 경사도에서는 가이드 형판의 영향이 크게 나타나지 않았다.(P < 0.05) 임플란트가 설측에 위치된 경우에 가이드 형판을 이용하는 경우 삭제 시작점의 정확성이 유의하게 높았다. 전반적인 구멍 삭제의 편차는 가이드 형판을 이용하는 경우에 적었다.

결론: CAD/CAM 방식의 가이드 형판은 나사 접근 구멍을 형성시 삭제 정확성을 향상시키고 보철물과 지대주의 손상을 감소시킨다.

핵심 되는 말: 임플란트, 나사 접근 구멍, 드릴 가이드, CAD/CAM, 정확도